Pending Claims:

Claims 1-10 are now pending.

Title of the Invention

The title of the invention has been amended to reflect the subject matter claimed, per the Examiner's request.

Subject Matter Indicated Allowed or Allowable:

Applicants are grateful for the indication of allowability of Claim 6, subject to its re-writing in independent form. Claim 6 has been re-written in independent form to include the limitations of independent Claim 1 and intervening Claim 5.

Art Rejection Under 35 U.S.C. § 103(a):

Claims 1-5 and 7 stand rejected under 35 U.S.C. § 103(a) as unpatentable over Mizuno, et al. (U.S. Pat. No. 5,876,325) and Klieman, et al. (U.S. Pat. No. 5,582,617). Applicants respectfully controvert the rejection. Claim 1 of the present invention sets forth first and second end effectors pivotally mounted for rotation about an end effector axis which is parallel to a primary axis of a robotic arm structure. The primary axis is defined as the axis about which θ motion proceeds and from which R motion radially proceeds and is located at the proximal end portion of a proximalmost arm of at least two arms of the robotic structure. A first motor is connected to rotate the first end effector about the end effector axis so as to provide an independent yaw motion for the first end effector, and a second motor is

A

connected to rotate the second end effector about the end effector axis so as to provide an independent yaw motion for the second end effector independent from the yaw motion of the first end effector.

Mizuno, et al. shows a surgical manipulation system having a pair of slave manipulators (3, 4) which are manipulated by a surgeon using a pair of corresponding master manipulators (16, 17). The manipulators each comprises a multiplicity of jointed arms, with the motion of master manipulators (16, 17), effected by the surgeon during a surgical procedure, being translated to corresponding motion of the slave manipulators (3, 4) to thereby permit the surgeon to operate on the patient from a remote location. Slave actuators 11 are provided to rotate the arms of the slave manipulators (3, 4) in accordance with controller 31, which, along with other devices, serves to translate the surgeon's motions of the master manipulators (16, 17) to commensurate motion of the slave manipulators.

Mizuno, et al. does not show rotation of two end effectors about an end effector axis which is parallel to a primary axis of a robotic arm, with the primary axis defining R and θ motion of the robotic arm. Mizuno, et al. also does not show the use of two motors, each associated with a corresponding one of the end effectors, to effect this rotation and thereby produce independent yaw motion for each end effector. The Mizuno, et al. device is not a robot at all, and is not autonomous, as the term robot is understood to mean, but is rather a complex mechanism for extending the reach of a surgeon from a remote location to the surgical site and enabling manipulation of surgical instruments from the remote location. The

Mizuno, et al. device requires real-time input from the operator and does not confront or address the problems of automatic robotic applications. In Mizuno, et al., operation is manual and is at speeds that are a fraction of those of automated semiconductor applications. Accordingly, in Mizuno, et al., considerations which are critical in semiconductor applications, such as flexibility of components, play a very minor role. The manual operation of Mizuno, et al. allows the actuators to be disposed relatively remotely from the operation site in the patient. From the remote actuators, mechanical linkages transfer motion to the instruments at the distal tip. Since operation is taking place in real time and with feedback from the human operator, component flexibility and tolerance within the system can be accounted for by the operator and the device operated accordingly. In automated, robotic operation, however, component flexibility and tolerance become major issues that have to be grappled with. By comparison to the relatively static situation of the Mizuno, et al., system, in the robotics applications the system has to be dynamically modeled, taking into account factors such as component elasticity, complex motion transmission systems, momentum, etc. A critical constraint in this situation is the proximity of the source of motion—that is, the motors—to the destination of the motion—that is, the end effectors. The greater the distance between these, the more influence elasticity and motion transmission systems have. Since accuracy, precision and repeatability are also very critical in semiconductor robotics applications—absolute accuracy to within one thousands of an inch and resolution of one ten-thousands of an inch, typically—adapting the system of Mizuno, et al., for automatic robotic operation imposes insurmountable physical and economic barriers. Accuracy and precision in semiconductor processing environments are controlled and maintained typically by using

encoders which relay to the control system the position of the various components—that is, the end effectors, the motor shafts, the arm links, etc. As the distances between motion source and destination increases, flexure and tolerances increase, and the disparity between the outputs of the encoders and the actual positions increases, and only when very complex and impractical dynamic modeling schemes are employed can accuracy and precision be maintained. As discussed above, this is not critical in the non-robotic applications of Mizuno, et al. because the human operator, working at relatively slow speeds, can take account of these. However, under the high through put production situations of semiconductor processing, this is not possible in a practical and economically viable manner. A design such as that of Mizuno, et al. would for all practical purposes prove dynamically unmodellable and could not be used in robotics. Moreover, in semiconductor processing applications, to which newly added Claims 9-16 are specifically directed, space considerations are critical. Typically, all the motors, encoders, end effectors, arm links and transmissions are disposed within the controlled semiconductor processing mini-environment. Therefore, motors can be placed close to the end effectors, and mechanical motion linkage can be minimized. (See Claims 2, 3, 11 and 12 for instance). By contrast, in Mizuno, et al., the space limitation is imposed by the patients body, and most of the components have to be disposed outside of that. As such, large distances between the actuators and encoders on the one hand, and the end effectors on the other, are introduced. As discussed above, this is impermissible in automatic semiconductor processing systems, especially systems utilizing two end effectors and two motors as claimed, wherein the use of both pairs compounds the precision, accuracy and dimensional constraints.

Klieman, et al. fails to remedy the shortcomings of Mitzuno, et al. in teaching or suggesting the present invention as claimed. Klieman, et al. shows a surgical instrument in which a pair of blades (160, 162) of a surgical scissors, referred to as the end effector, are pivotally mounted at the end of a barrel (6), again for extending the reach of a surgeon from a remote site to the surgical site. Like Mizuno, et al., Klieman, et al. fails to show rotation of two end effectors about an end effector axis which is parallel to a primary axis of a robotic arm, with the primary axis defining R and θ motion of the robotic arm. Klieman, et al. also fails to show the use of two motors, each associated with a corresponding one of the end effectors, to effect this rotation and thereby produce independent yaw motion for each end effector, with the yaw motion being defined relative to an end effector axis parallel to the primary axis of a robotic arm. The Klieman, et al. device is not robotic in nature and does not have a robotic arm structure including at least two links whose motion is defined relative to a primary axis. Moreover, in Klieman, et al. the blades comprising the end effector—and indeed it should be noted that only one end effector is disclosed in Klieman, et al.—are not mounted for independent motion. Rather, the motion of the blades is mechanically linked, with one blade being used for example to leverage the other blade in order to effect opening or closing of the scissors. And again, since the Klieman, et al. device is not a robot at all, it requires real-time input from the operator and is thus clearly distinguishable from the present invention, and even if a combination of Kieman, et al. and Mizuno, et al. were properly motivated, such a combination would not achieve the presently claimed device, without requiring further, unobvious modifications.

New dependent Claims 8 and 10 take the distinction of the present invention over the applied prior art a step further and recite that the robotic arm structure is adapted to operate automatically and independently of real-time operator input. This is in clear distinction from either Mizuno, et al. and Klieman, et al., both of which disclose devices which serve merely to translate, directly and in real-time, an operator's actions to corresponding actions performed at a different location. As discussed above, in Mizuno, et al. this is effected using slave manipulators (3, 4) which follow the actions of master manipulators (16, 17) manipulated by the surgeon, while in Klieman, et al. it is effected using a scissors disposed at one end of a barrel (6) and mechanically linked to a handle (4) at the other end. Automatic operation, independent of real-time operator input, is neither taught nor suggested by the applied prior art, singularly or in combination.

Conclusion:

In view of the preceding discussion, applicants respectfully urge that Claims 1-8 of the present application define patentable subject matter and should be passed to allowance. Such allowance is respectfully solicited.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By: ______________________
Khaled Shami
Registration No. 38,745

Post Office Box 1404
Alexandria, Virginia 22313-1404
(650) 854-7400
Date: September 17, 1999